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Thesis.

"The Parr Calorimeter".

Presented for the degree of
Bachelor of Science in Mechanical Engineering.

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20 May 1948. Ser. g. Univ., H. Evans Roberts

The object of this thesis is the investigation of the Parr Coal Calorimeter with regard to the uniformity of results and the accuracy of the instrument as determined by sets of readings obtained from various samples of coal.

Fig II. represents a cross section view of the Parr Calorimeter, ready for use. The instrument consists of a cylindrical cartridge, made of copper, nickel plated on the outside, open at both ends and the inside capacity of which is about twenty-five cubic centimeters. Both ends are threaded, by means of taps, for a short distance to receive the end pieces, and are also flanged at the ends to give a larger bearing surface for the end pieces thereby reducing the liability of water getting into the inside of the cartridge. Fig I shows

in detail across a sectional plan view of the cartridge with its threads and flanges. The two end pieces are shown at E and E' in the same figure, the former being the bottom piece and the latter the top. [illegible] is the threaded portion which screws into the lower part of the cartridge and the connection is made water tight by a rubber washer x. The end of this piece is knurled to enable a firm hold being obtained when it is screwed in. In the middle of this piece is a conical hole C. The upper end is provided with threads and a washer also, but has a portion shown, cylindrical and hollow, which encloses a valve, used principally during the process of filling the engine. Inside of the steel sleeve V', [illegible]

hollow cylinder C' made of brass, threaded at the end S, and having its lower end enlarged to cover the passage between the stem and the interior of the cartridge, thus excluding the air. This brass piece fully shown in Fig I, is cylindrical to the point P, and from P to the bottom there is a key way cut in it to make the passage for expression larger and quicker. The upper end of the brass stem screws into cap K, which is of brass threaded to screw on the stem. The cap is hollow and has a diameter, internal, equal to that of the brass stem, forming a continuous passage from the top of the cap to the cartridge. Between the outer and inner stems and formed by a shoulder on the outer stem is a space S', in which a spring

is placed pressing on the lower edge of the cap, and consequently when the cap and with it the valve stem attached to it, is pressed downward, communication is made with the interior of the cistern E. On releasing the pressure, the stem springs upward closing off the cistern edge very rapidly. The valve, cistern edge, stem and valve, rest on a conical pivot supported at A Fig II. Three radial arms r r, only two are shown in the figure, project from A and are equal in length to each other and to the internal diameter of the vessel V, nearly. To these three radial arms is added a collar M, Fig II. V is an upper cylindrical vessel open at the top and nickel plated on the outside. The capacity of the vessel is a little

over the cistern. The other point and [illegible] placed at the bottom of the vessel and the thermometers [illegible] differing the point are [illegible] on [illegible] [illegible] part [illegible] the [illegible] the point [illegible] and [illegible] the centre of the vessel. The inner vessel V, is surrounded by two outer vessels made of indurated fibre, and represented by G and H, Fig II. These vessels are separated into [illegible] by the air spaces of [illegible]. The vessel V rests on three pegs fixed to the bottom of the vessel G. One of these pegs is shown at L, Fig II. These pegs provide an air space between the bottoms of vessels V and G. Between the bottoms of the two outer vessels, [illegible] is placed [illegible]. The cover of the apparatus, H', is [illegible]

of the same material as the outer vessel, and is not quite so as to leave a small space between. These parts are connected together by means of screws K K' Fig. II. For convenience in handling bail is attached (this is large enough to receive the stem) the [illegible] and the [illegible] for the passage into the [illegible] is to take a small pulley D, Fig. II. which is provided with a groove. This pulley is revolved by means of a string a pulley on a small water motor shaft. When the pulley revolves the entire cartridge revolves about the central point at the bottom. The cartridge is provided with bottom rings WW and these rings are perforated and these perfora- with the centre of the inside of the cotton

The cover also has another hole through which the thermometer T, passes. To prevent the thermometer slipping through and striking the vessel on the inside, a washer is placed on the top of the thermometer and tightly around the stem. The experiment in the calorimeter was tried. This thermometer reads between sixty and ninety degrees Fahrenheit and each degree was subdivided into twenty parts, making each division of the thermometer equal five hundredths of a degree. The bulb of the thermometer was placed that of the thermometer in the vessel V and sufficiently far from the casting, not to touch it.

A fuel calorimeter is an instrument for measuring the heat value of fuels as determined by their perfect combustion under such conditions that the heat evolved by the combustion of the fuel can be absorbed and measured. In any calorimeter two things are essential: first the combustion must be perfect and, second the heat evolved must be absorbed and measured. // The combustion can take place in atmospheric air, in oxygen gas or in combination with a chemical that supplies the oxygen required. / It is necessary that the supply of oxygen be sufficient for perfect combustion. In the case of the Parr calorimeter a chemical is used and mixed with the coal. This

← WORD FOR WORD AS IN CARPENTER P 415 ART 248

chemical is sodium peroxide. The charge, which is placed in the cartridge, is ignited by dropping a hot copper wire of known length and gauge into the charge by means of the valve and stem. It is evident then that a correction factor must be used for heat given up by the wire. From a number of experiments conducted by the author the average value of heat given up by the wire was 215° Fahr. or .0071 of the total heat given. This amount must be subtracted in computing results. A second correction is necessary because of the heat resulting from the combination of the products of combustion, carbon dioxide (CO_2) and water, with the chemical used. This heat of combination

can as in [illegible] mentioned above the radiant heat of [illegible] amounting to twenty seven per cent of the total indicated heat. The method of calculating is as follows. Supposing a [illegible] calorimeter to be used and B' represents the total indicated heat units. Let B represent the actual heat units due to combustion, t the rise in temperature and W the water used. Then B' will have the value $(t^\circ - .015^\circ) \times W$ and B the value $B' - \frac{B' \times 27}{100}$ Solving this equation we have

$$100B = 100B' - 27B'$$

$$100B = 73B'$$

$$\frac{100}{73}B = B'$$ Now substitute this value of B' in the first equation and

$$\frac{100}{73}B = (t^\circ - .015^\circ)W$$ or

$$B = .73 \times (t^\circ - .015^\circ) \times W$$

By multiplying the result by five-ninths the answer is given in calories, the formula used being in British Thermal Units. The method of obtaining the factor for the heat absorption of the products of combustion is as follows: The two elements concerned are carbon and hydrogen. For the carbon dioxide resulting from the combustion of the former, the correction factor is easily deduced. Pure sugar carbon is prepared and the proper amount weighed, mixed with the chemicals and fired. From a number of determinations of [illegible], performed by the manufacturers of the instrument, a total result of 11,0[illegible] calories was found. Taking [illegible] of [illegible] resulting from the [illegible]

of combustion of the carbon. The increase in such case, due to the heat of dissociation of the carbon dioxide of 11054 − 8050 or 3,004 calories. This is $\frac{3004}{11054}$ of the total heat or 27.1%. That due to the absorption of water from the combustion of hydrogen in the same way was difficult to obtain, the burning of sugar being rather indicative, compounds other than water are formed. After many methods had been tried, empirical data was finally resorted to, obtained from burning widely different varieties of coal and comparing the results of the same coals in standard bomb calorimeters. The actual size of the copper wire used was a number twelve gauge and the weights of an inch in length. In determining

the actual value of the factor to be used for the correction of heat due to the combustion of C. and H_2 with the chemical. The water equivalent of the metal in the instrument to be used must be determined and also the amount of water used in the experiment. The water used is 2000 cubic centimeters at 60° Fahr. There are several methods for obtaining the water equivalent. By finding the sum of the products of the weights and specific heats of the various constituents of the calorimeter. By comparing the results obtained, by those which have been found by combustion of some fuel whose calorific power is known for instance, pure carbon in oxygen gas. By injecting off a steam of known pressure

and weight. The water used plus the water equivalent of the instrument was found to be 2123.5 grams. In the reaction 73% of heat is due to the combustion of the coal and 27% is due to the heat of combination of CO_2 + H_2O with the sodium peroxide. Now as one half gram of coal used this was 2123.5 grams of water to rise "X" degrees and if but 73% of this is due to combustion .73 X 2123.5 X 2 X "X" is the rise in temperature that would result from the combustion of an equal weight, 2123.5 grams, of coal is .73 X 2123.5 X 2 = 3100.3 The rise in temperature would be the same for any other quantities of coal and water that are equal in amount, as one pound of coal and one lb. of water, hence the B.T.U. per lb. of coal. To obtain the complete

working furnace, 310 must be substituted for B and we get

$$B = 310(t^\circ - 113^\circ)$$

Method of Making Test.

The moisture in air-dry coal varies from one to fifteen or more percent. When the percentage is above two or three percent, the variation due to the [illegible] of the coal [illegible], would be sufficient but to guard against a possibly greater percentage of moisture being present the coal should be dried in an oven. To obtain a sample of coal to be used, a bucket full was ground in a large

coffee mill operated by belting, driven by gas engine. It was then ground still finer by the same means and placed in a rubber-lined bucket. Five hundred grams were then taken, one from the middle and four at equal distances around the sides, and all placed in a glass jar with an air tight cover to exclude moisture as entirely as possible. The object of taking the [illegible] used as one sample, instead of 1, is to ensure that the coal has been thoroughly mixed and that a "fair" sample has been obtained. From all of these the sample was passed through the hundred mesh sieve and then finely powdered & first placed on a watch glass and both put in a copper oven provided with a centigrade thermometer, and heated at a temperature of from

105° to 110° C. for 45 minutes. The coal and glass are then weighed with the cover and the coal is covered over with another watch glass to exclude the air, and the glasses clamped together by means of a steel clamp. Upon a watch glass that has been carefully counter-poised on a pair of scales according to one tenth of a milligram weigh one half gram of the coal first heated and weigh until the proper amount has been obtained [illegible] the coal over with a second watch glass and clamp as before. Fill the glass flask with [illegible] water to the mark on the neck. The volume of water, the weight and [illegible] with the flask, being [illegible] at 60° F. Weigh the vessel. [illegible] the inside [illegible] and [illegible]

on any of these parts would carry the
amount of water to other than the proper
amount. Pour the water back [illegible]
of the vessel and [illegible] water from
the flask, taking care not to waste
any of it. Now place the vessel in
the (fig 3) of the inner fire vessel, being
careful not to spill any water on the
air space and thereby increase the
amount of radiation. Take the [illegible]
end of the cartridge and screw it firmly
in its place. Remove the lamp from
the water glass and [illegible] the [illegible]
with the cartridge with a camel's hair
brush. Place the cartridge, [illegible]
the operation on a sheet of clean paper
so that any coal spilled may be
replaced. The [illegible] should be
kept in an ordinary [illegible] jar
with an air tight cover. A [illegible]

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measure, with a handle, used for putting the chemical into the cartridge. The measure is made to hold from 8½ to 9 grams of chemical, when tapped to settle the contents and when the excess at the top is shaken off to correspond to a "struck" measure. The amount of the chemical weighs from about 17 to 18 times the amount of cork. Occasionally shake the jar of the chemical and the measure provided [illegible] carrying the chemical around stations. After measuring the chemical and putting it in the cartridge, put the measure back into the jar and screw the lid on tightly. Otherwise some of the chemical spoils in the air. Now screw on the upper end of the cartridge with the [illegible] and valve

and with the thumb pressed against the cap to prevent the valve from moving, thereby spilling the chemical, shake thoroughly to mix the soda and chemicals. After carefully to shake any of the mixture from the sides and press down the valve tube that it is working properly. Follow the same [illegible] if possible, adjust the cap [illegible] bottle [illegible] and place the [illegible] in the centre of the vessel V, pressing the [illegible] down to the [illegible] point. [illegible] the instrument, fitting the [illegible] which [illegible] projecting part of the [illegible] piston. [illegible] the pushing of the [illegible] into the [illegible] spring. The [illegible]

enable the water currents to be deflected downward. To give this motion it was necessary to use a crank & long stiff [illegible] of the thermometer and adjust until the thermometer [illegible] through the tube [illegible] the bottom of the sediment. This [illegible] the [illegible]. I used the water [illegible] with the motor and adjust until the proper number of revolutions per minute of the [illegible]. The best speed [illegible] with the [illegible] revolutions per minute. [illegible] with the [illegible], [illegible] from the [illegible] at the centre of the

[illegible] with the top of the mercury column, to avoid error in reading. When a constant temperature is reached, note reading of thermometer and insert the copper wire in the flame of a Bunsen burner [illegible] copper wire with a pair of pincers. Keep wire in the flame until it is [illegible] heat, then drop quickly into the [illegible] and after the [illegible] the mixture will be [illegible]. Do not hold the [illegible] down but allow it to spring back as soon as possible. The cooling [illegible] Care must be taken [illegible] putting the copper in the [illegible], if any [illegible] delay [illegible] the copper to cool, [illegible] that there is insufficient heat in the wire [illegible] the change.

The combustion is indicated by a white fumes of [illegible] possible [illegible] coming out the [illegible], and by a rapid rise of the mercury column. Take reading of the thermometer when it reaches its highest point. Pour off water sufficient to the [illegible], [illegible] stirring, then [illegible] the thermometer and take [illegible] from it. Wipe it off and put it [illegible] that it will not be broken. Remove the pulley from the stem, [illegible] the [illegible] under [illegible] the cartridge. [illegible] the water from the cartridge and take off the [illegible]; [illegible] the water in the vessel back into the flask as the [illegible] water [illegible] repeatedly. [illegible] the [illegible] water on the outside [illegible]

ends of the cartridge [illegible] cap [illegible] removing the [illegible] spring and cap to be removed from the [illegible] and placed [illegible] the part under running water. The residue in the cartridge is dried in the oven. After [illegible] part [illegible] free from [illegible], [illegible] of the [illegible]. [illegible] them in the oven to dry. While these determinations are being carried out, have another sample of coal in the oven, drying so that time will be saved. Dry the [illegible] and the part [illegible] before weighing them again. When the parts [illegible] are thoroughly dry [illegible] of [illegible] test. [illegible] to [illegible] in the [illegible]

and if a [illegible] is so filled [illegible] with water at once. The mixture of coal and [illegible] water [illegible] and it is for this reason that the crucible must be thoroughly dried before a charge is put into it. These [illegible] the test.

The sugar coke was made by burning granulated sugar in an open porcelain dish placed over a Bunsen burner. [illegible] the sugar [illegible]. The charcoal was then put in a crucible with a tight cover and heated up to a white heat by a blast lamp, for half an hour, converting the charcoal to coke. The coke was then tested for

cake by burning some of it in air, in the bulb of a porcelain dish, but the amount of ash present was inappreciable. A great deal of trouble was experienced in firing the cake, a special chemical for the purpose being used, and also the sodium peroxide, but the charge could not be ignited. By trial it was finally obtained by mixing with the ½ gram of cake, ½ gram of a sample of coal whose heat value had been previously determined. A definite amount of chemical was required to furnish the oxygen. To obtain the heat value of the cake the total number of heat units due to the coal and chemical combined, was found and the value for coal subtracted from the total number to give the value of the cake. In this way satisfactory results were obtained and are tabulated as given

in igniting the charge.

Method of Working Results.

In working the results the temperature as given by the thermometer is read after the temperature had become constant and after the charge was fired the thermometer is read again when it reached its highest point. The first temperature was subtracted from the second and .015° correction for the fuse wire — subtracted from the result. This final result multiplied by 2110 gave the B.T.U. per lb. of coal. After making the tests of samples from the same coal the probable error of the [illegible] was found and then the probable error of the final result [illegible] giving the probable error of the calculations. Formula [illegible]

obtained it was found that five readings would be accurate enough to give a good mean value, so that in all succeeding samples but five readings were taken. In working out the probable error the formula $= \sqrt{\frac{\Sigma\Delta^2}{n(n-1)}}$ was used where n is the number of observations and $\Sigma\Delta^2$ the sum of the squares of the difference between each reading and the mean of all the readings. A sample calculation of the first ten readings and their probable error follows.

Sample of Soft Coal.

Observation number	1st Temp.	2nd Temp.	Diff with corrections D	B.T.U. per lb. of coal
1	73	$77\frac{13}{20}$	4.635	3100D = 14368.5
2	$77\frac{7}{40}$	$81\frac{27}{40}$	4.485	3100D = 13903.5
3	$73\frac{13}{20}$	$78\frac{13}{40}$	4.66	3100D = 14446.0
4	$74\frac{4}{20}$	$78\frac{19}{20}$	4.735	3100D = 14678.5
5	$74\frac{4}{20}$	$78\frac{29}{40}$	4.51	3100D = 13981.0
6	$80\frac{1}{20}$	$84\frac{16}{20}$	4.735	3100D = 14678.5
7	$78\frac{1}{20}$	$82\frac{13}{20}$	4.585	3100D = 14213.5
8	$76\frac{19}{20}$	$81\frac{23}{40}$	4.61	3100D = 14291.0
9	$77\frac{16}{20}$	$82\frac{8}{20}$	4.585	3100D = 14213.5
10	$78\frac{39}{40}$	$83\frac{8}{20}$	4.41	3100D = 13671.0

Probable Error of 1st 5 readings

		Δ	Δ^2
1.	14368.5 − 14275.5	113	12769
2.	13903.5 − 14275.5	372	138384
3.	14446.0 − 14275.5	171	29241
4.	14678.5 − 14275.5	403	162409
5.	13981.0 − 14275.5	294.5	86730.25
			429533.25

Prob. Error = [illegible] $\sqrt{\frac{429533.25}{20}}$ = [illegible]

Mean Value of 1st 5 readings 14275.5

Probable Error of 2nd 5 Readings

Mean Value of 2nd 5 Read. = 14213.5

	Δ	Δ
6. 14678.5 - 14213.5	465.0	= 216225
7. 14213.5 - 14213.5	0	0
8. 14291.0 - 14213.5	77.5	6006.25
9. 14213.5 - 14213.5	0	0
10. 13671.0 - 14213.5	542.5	294306.25
		516537.5

P. E. Mean $= \frac{2}{3}\sqrt{\frac{516537.5}{20}} = \underline{\underline{107.1}}$

Probable Error of ten Readings.

	Δ	Δ^2
1. 14368.5 - 14244.5	124	15376
2. 13903.5 - 14244.5	341	116281
3. 14446.0 - 14244.5	201.5	40602.25
4. 14678.5 - 14244.5	434	118356
5. 14275.5 - 14244.5	31	961
6. 14678.5 - 14244.5	434	118356
7. 14213.5 - 14244.5	31	961
8. 14291.0 - 14244.5	46.5	2112.25
9. 14213.5 - 14244.5	31	961
10. 13671.0 - 14244.5	573.5	328329
		742295.5

Prob. Error $= \frac{2}{3}\sqrt{\frac{742295.5}{90}} = \underline{\underline{60.6}}$

Mean Value of 10 readings = 14244.5

Result of Computations

No. of Readings	1st temp.	2nd temp.	B.T.U. per lb of coal
1	$84\frac{9.5}{20}$	$88\frac{4.5}{20}$	11578.5
2	$79\frac{16}{20}$	$83\frac{12}{20}$	11733.5
3	$82\frac{17}{20}$	$86\frac{7}{20}$	11578.5
4	$84\frac{6}{20}$	$87\frac{19}{20}$	11268.5
5	$84\frac{8}{20}$	88	11113.5

Mean Value of 5 Readings = 11454.5

Probable error of 5 Readings

	A	A^2
1, 11578.5 - 11454.5	124	15376
2. 11733.5 - 11454.5	279	77841
3. 11578.5 - 11454.5	124	15376
4. 11268.5 - 11454.5	341	116281
5. 11113.5 - 11454.5	186	34596
		259470

$$\text{Prob. Error} = \frac{2}{3}\sqrt{\frac{259470}{20}}$$

$$= \frac{2}{3} \times 113.9 = 75.94$$

Sample of Sugar Coke.

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	$77\frac{18}{20}$	$85\frac{18}{20}$	24753.5	13299
2	$72\frac{18}{20}$	$80\frac{18.75}{20}$	24869.7	13415.2
3	$72\frac{4}{20}$	$80\frac{8}{20}$	25373.5	13919.0
4	$76\frac{3}{20}$	$84\frac{5}{20}$	25063.5	13609.0

[illegible] Coke = 13560.5

Probable error	Δ	Δ^2
1. 13299 -13560	261.5	68382.25
2. 13415.3 -13560	145.3	21112.09
3. 13919.0 -13560	358.5	[illegible]
4. 13609. -13560	148.5	22052.25
		250068.84

$$\text{Prob. Error} = \frac{2}{3}\sqrt{\frac{250068.84}{12}} = \frac{2}{3} \times 144.3 = \underline{\underline{96.}}$$

Sensibility of [illegible]

Observations	1st temp.	2nd temp.	[illegible]
1	75 9/20	77	9718.5
2	75 [illegible]	77/[illegible]	9842.5
3	78 [illegible]	[illegible]	9951.0
4	81 [illegible]	84 [illegible]	9912.25
5	78 [illegible]	81 [illegible]	9951.0

Mean value = 9875.05

Probable error.

		Δ	Δ²
1.	9718.5 − 9875	156.5	24492.25
2.	9842.5 − 9875	32.5	1056.25
3.	9951.0 − 9875	76	5776
4.	9912.25 − 9875	37.25	1387.56
5.	9951.0 − 9875	76	5776
			38488.06

Prob. error = $\frac{2}{3}\sqrt{\frac{38488.06}{\text{[illegible]}}}$ [illegible]

Sample of [illegible] Valley Mine Coal

Observation	1st temp.	2nd temp.	B.T.U. per lb. of coal.
1	69 10/20	73 [illegible]/20	12198.5
2	72 1.7/20	76 6.8/20	[illegible]
3	75 2.5/20	78 [illegible]/20	11888.5
4	76 12/20	80 [illegible]/20	12741
5	75 10/20	79 12.3/20	12431

Mean Value = 12221.7

Probable Error	Δ	Δ^2
1. 12198.5 − 12221.7	23.2	538.24
2. [illegible] − 12221.7	372	[illegible]
3. 11888.5 − 12221.7	333.7	111355.69
4. 12741 − 12221.7	519.3	269672.49
5. 12431 − 12221.7	209.3	43806.44
		[illegible]

$$\text{Prob. Error} = \frac{2}{3}\sqrt{\frac{563[illegible]}{20}} =$$

$$\frac{2}{3} \times 167.8 = \underline{\underline{111.86}}$$

[illegible]

Mixed with Sykens Valley Rice Coal.

Number	1st Weigh.	2nd Weigh.	B.T.U.	B.T.U. per lb of Coke.
1	$76\frac{14}{20}$	$84\frac{18}{20}$	25373.5	13151.8
2	$74\frac{3.75}{20}$	$82\frac{7}{20}$	25265.0	13043.3
3	[illegible]	$82\frac{11.57}{20}$	25663.5	13461.8
4	[illegible]	[illegible]	25666.0	13384.3
5	$75\frac{13.75}{20}$	84	25733.25	13531.55

Mean value of Coke = 13314.53

Probable Error.	Δ	Δ^2
1. 13151.8 - 13314.53	162.73	26481.05
2. 13043.3 - 13314.53	271.23	73449.44
3. 13461.8 - 13314.53	147.21	21617.21
4. 13384.3 - 13314.53	69.77	[illegible]861.75
5. 13531.55 - 13314.53	217.02	47089
		173583.73

Probable Error = $\frac{2}{3}\sqrt{\frac{173583.73}{20}}$

$= \frac{2}{3} \times 93.1 = \underline{62.06}$

Sample of Newton's White Ash – Coal

Observation	1st temp.	2nd temp	B.T.U. per lb. of Coal
1	75	79 5/20	13128.5
2	77 18.5/20	81 14/20	12818.5
3	80 19/20	85 10/20	14105.0
4	80 17.5/20	84 9/20	13523.75
5	77 19/20	82 6/20	13485.0

Mean Value = 13412.5

Probable Error	Δ	$Δ^2$
1. 13128.5 − 13412.5	283.65	80428.96
2. 12818.5 − 13412.5	593.65	352360.96
3. 14105.0 − 13412.5	692.65	[illegible]
4. 13523.75 − 13412.5	111.1	[illegible]
5. 13485. − 13412.5	72.85	5307.12
		939523.44

Prob. Error =

$$\frac{2}{3}\sqrt{\frac{939523.44}{20}}$$

$$=\frac{2}{3}\times 216.7 = 144.4$$

Example of [illegible]

Series 2 with [illegible] White Metal [illegible]

Observation	1st temp	2nd temp	Total R.T.U	R.T.U for [illegible]
1	73 13/20	82 11.5/20	26071	12658.85
2	76 8/20	85	26613.5	13201.35
3	78 [illegible]/20	87 [illegible]/20	[illegible]	[illegible]
4	79 6/20	87 17/20	26458.5	13046.0
5	75 3/20	83 15/20	26613.5	13201.35

Mean Value = 13046.28

Probable Error	A	A^2
1. 12658.85 − 13046	388	150544.
2. 13201.35 − 13046	155	24025
3. 13123.85 − 13046	77	5929
4. 13046.0 − 13046	0	0
5. 13201.35 − 13046	155	24025
		204523

Prob. error = $\frac{2}{3}\sqrt{\frac{204523}{20}}$ = 67.8

Conclusion.

From the results obtained it will be seen that the readings have but small variations and that in every case the result differs from the mean value by a very small percentage. The instrument is easy to manipulate, simple in construction and the method of fixing the charges in question is simple. The chemical is dangerous and special care must be taken when it is handled. The length of time of heating the wire is specified in the circular as ten seconds, but it was found that the wire could not be heated to a white heat in less than twenty or thirty seconds. But once in all the tests made, did the ratchet fail to spring back and [illegible] the [illegible] charge [illegible] up through the [illegible]

but with no decisive results. The water in it, caused so much trouble that it was difficult to obtain the proper speed; [illegible] [illegible] [illegible] water being insufficient. It was noted at the beginning of each feeding, required a little more coal [illegible] [illegible] fire, for a fair amount of the steam being required to drive the machine for [illegible] use. After the first test it was considered [illegible] required testing. The amount of coke, although free from [illegible], and water was within fifteen hundred heat units for a value of [illegible]. The results obtained were [illegible] satisfactory and the whole test was considered reliable and accurate.

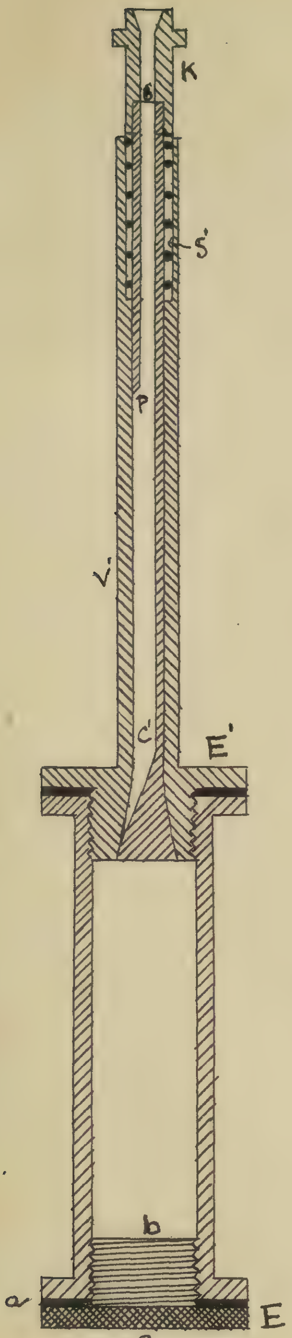

Fig I

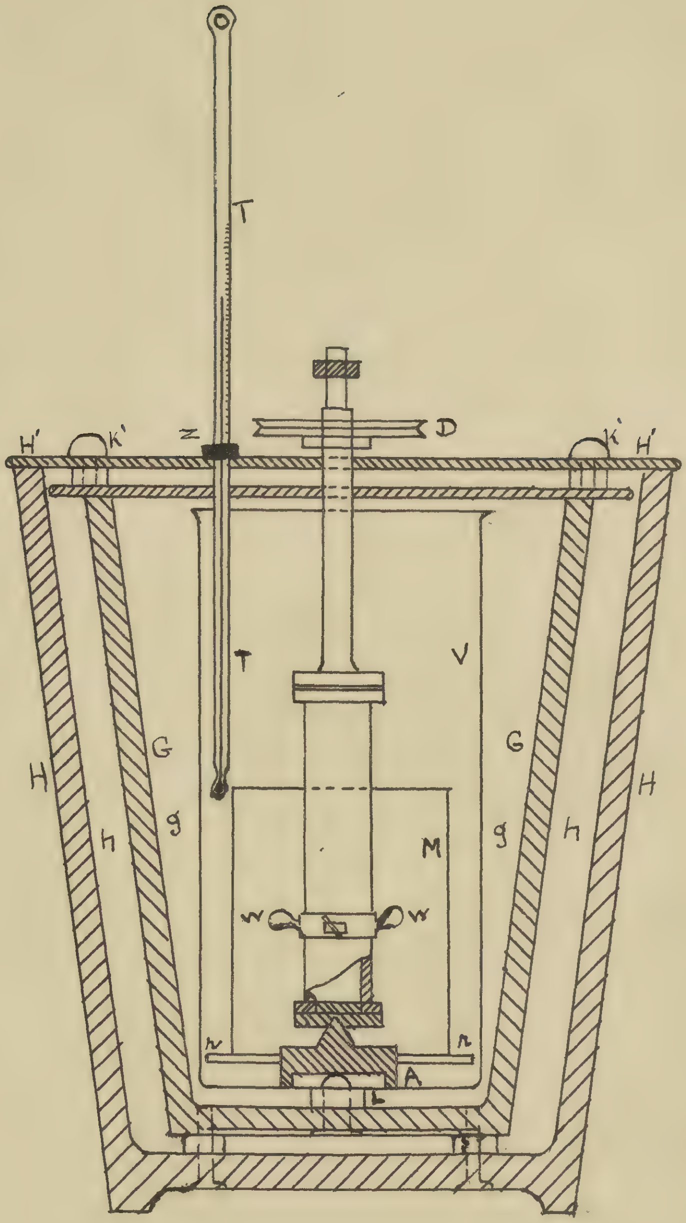

Fig 2

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